

High Pressure Synergetic Consortium (HPSynC) at the Advanced Photon Source

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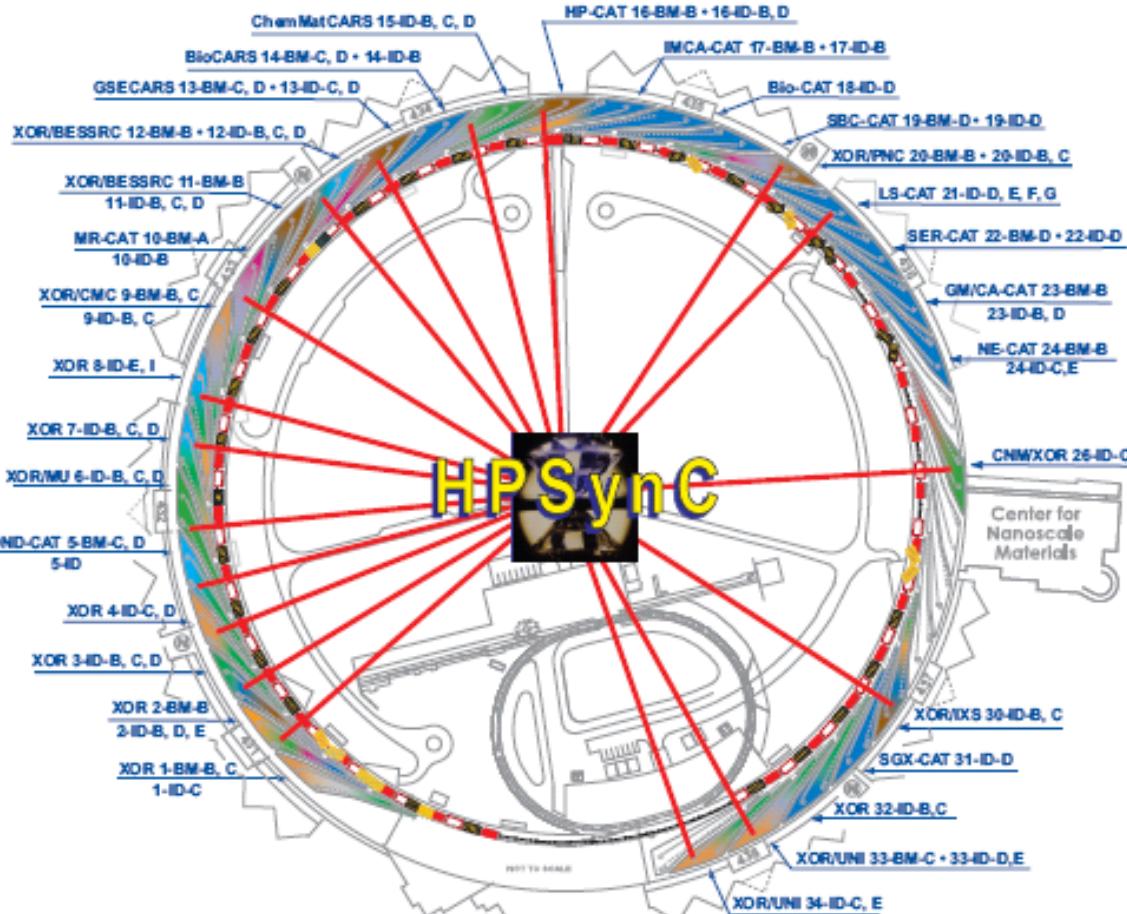




HPSynC

High Pressure Synergetic Consortium
at the Advanced Photon Source

Established in 2007



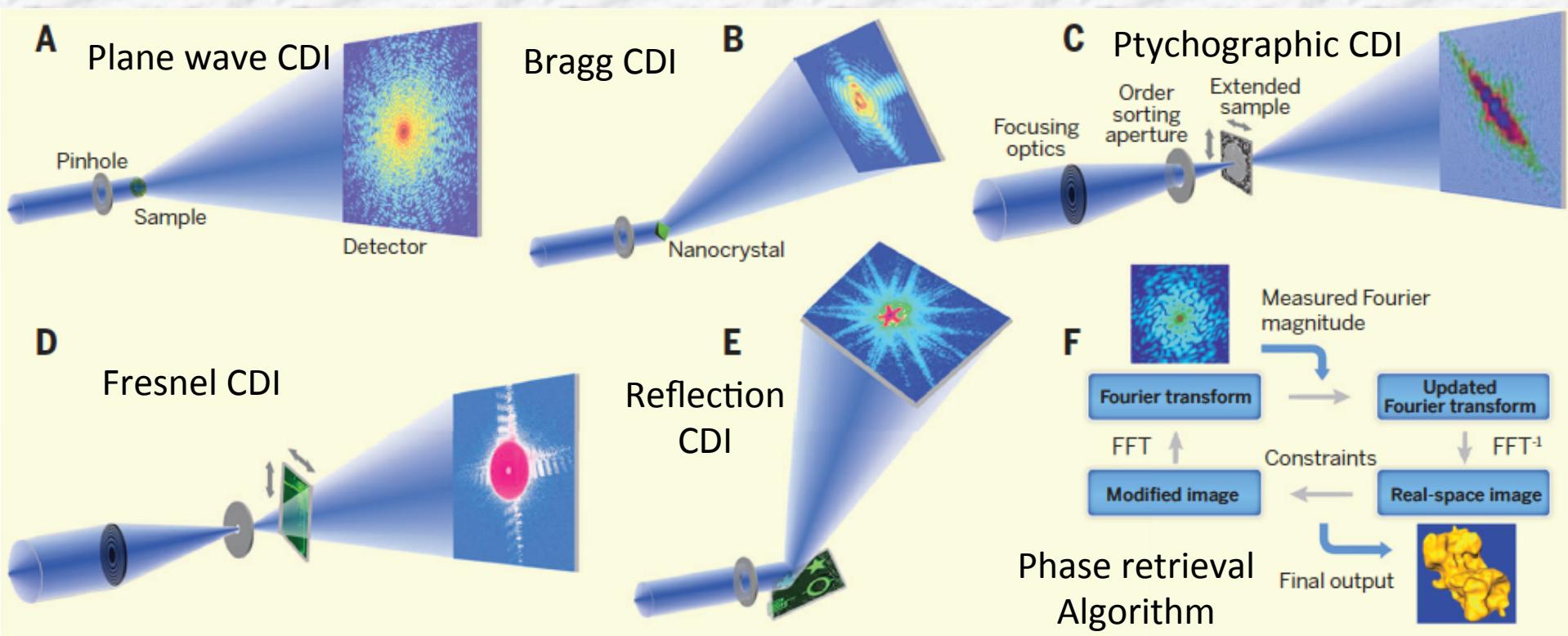
We are looking the capabilities beyond the dedicated high pressure beamlines !

Mission:
develop high risk, high return, high pressure synchrotron sciences and Technologies

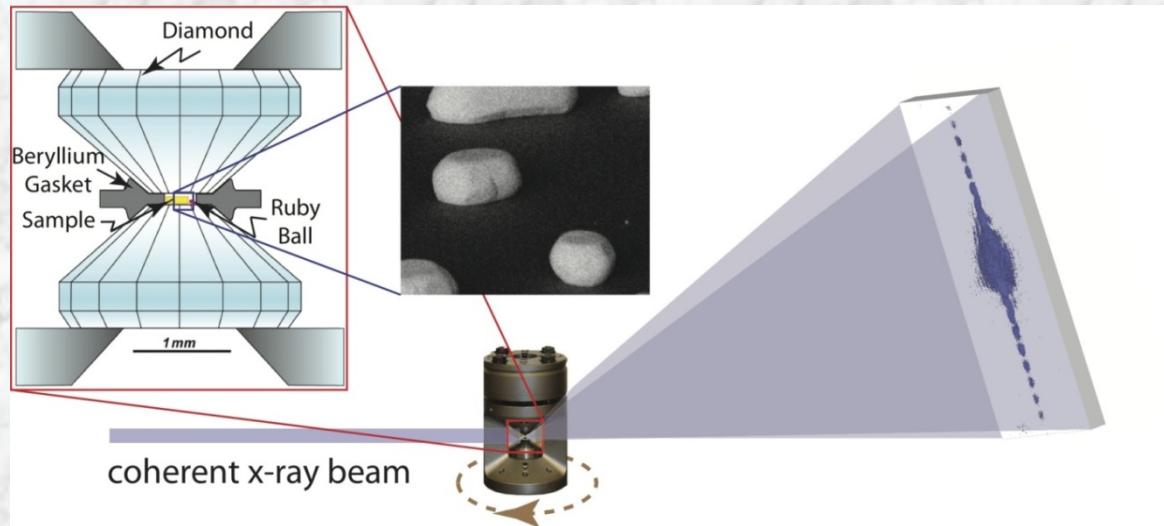
current focus Activities
New science and novel HP-SR techniques
Nano imaging (TXM), diffraction Coherence (CDI)
High energy scattering (PDF)
High energy resolution (HERIX, MERIX)
Various novel spectroscopy
Time resolved (Shock wave, XPCS)
Magnetic study (XMCD)

Coherence provides great information regarding 3d density, lattice displacement, dynamic relaxation time ...

APS-U will provide 2 orders of magnitude enhancement on coherence;
High Pressure community has not benefited most from this capability.



We demonstrated the first successful observation of elastic strain and plastic flow evolution in a 400 nm gold nanocrystal using coherent diffraction imaging under high pressure

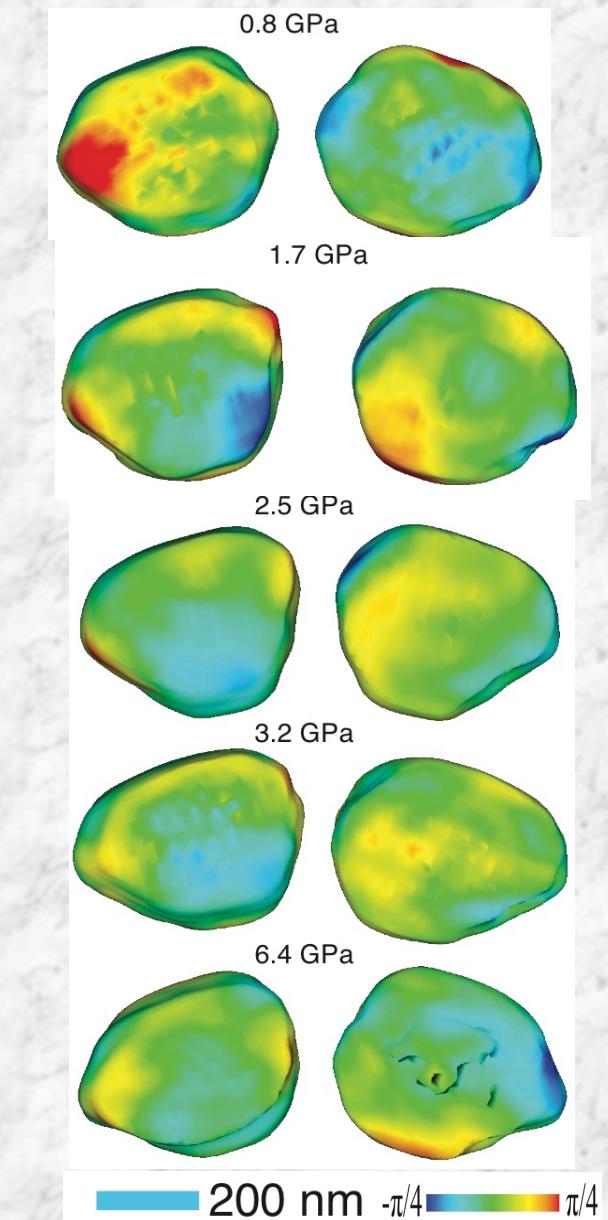


Experimental setup at 34ID-C, APS

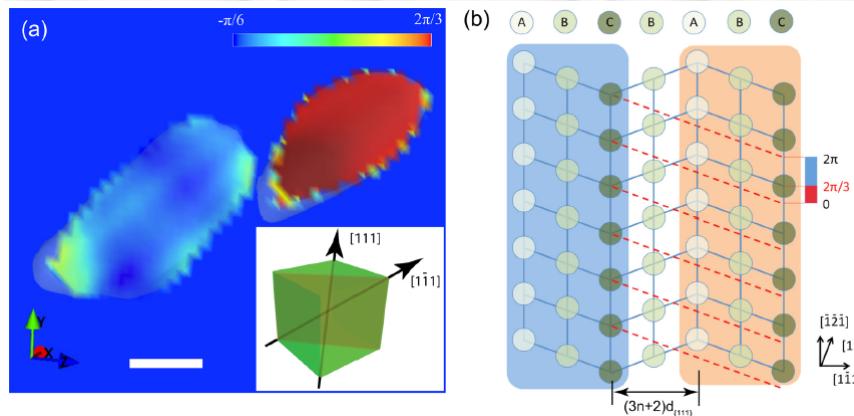
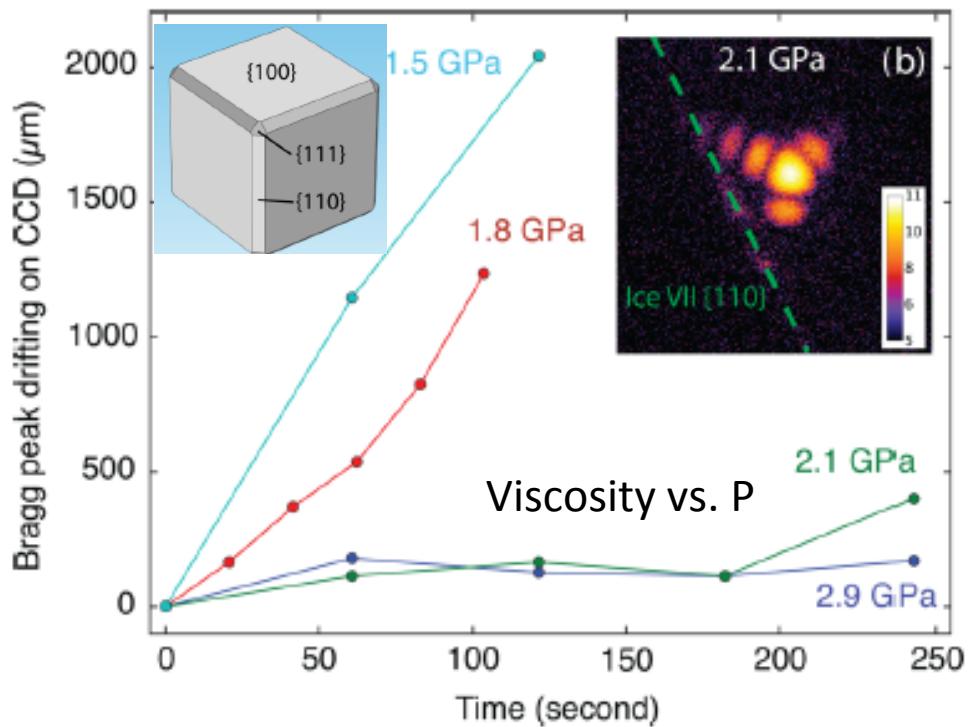
Yang, Mao et al.

“Coherent diffraction imaging of nanoscale strain evolution in a single crystal under high pressure”

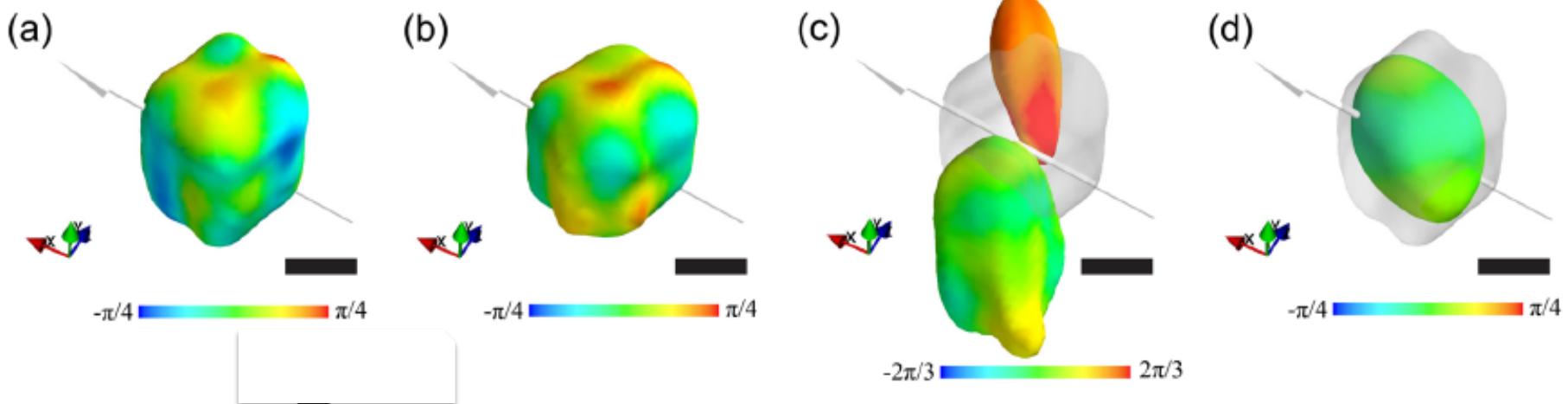
Nature Comm. 4, 1689 (2013)



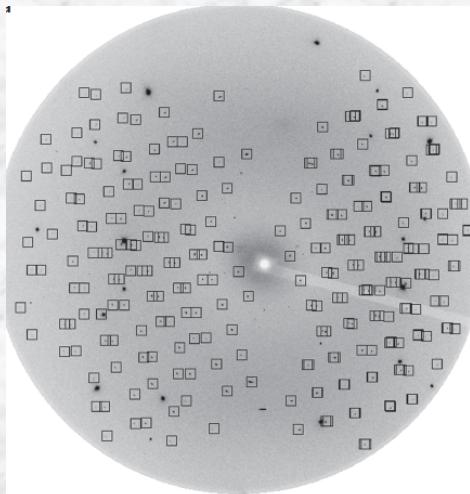
Deformation twinning process observed with consequent CDI measurement in a 100nm Ag



Huang, Yang, Mao et al.
“Deformation Twinning of a silver nano-crystal under High Pressure”
Nano Lett. 15, 7644(2015)

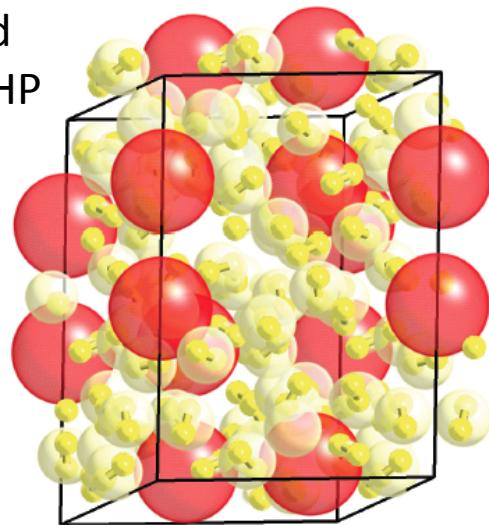


High Pressure Single Crystal Structure enables structural determination of new compound and new pathway of structural transition



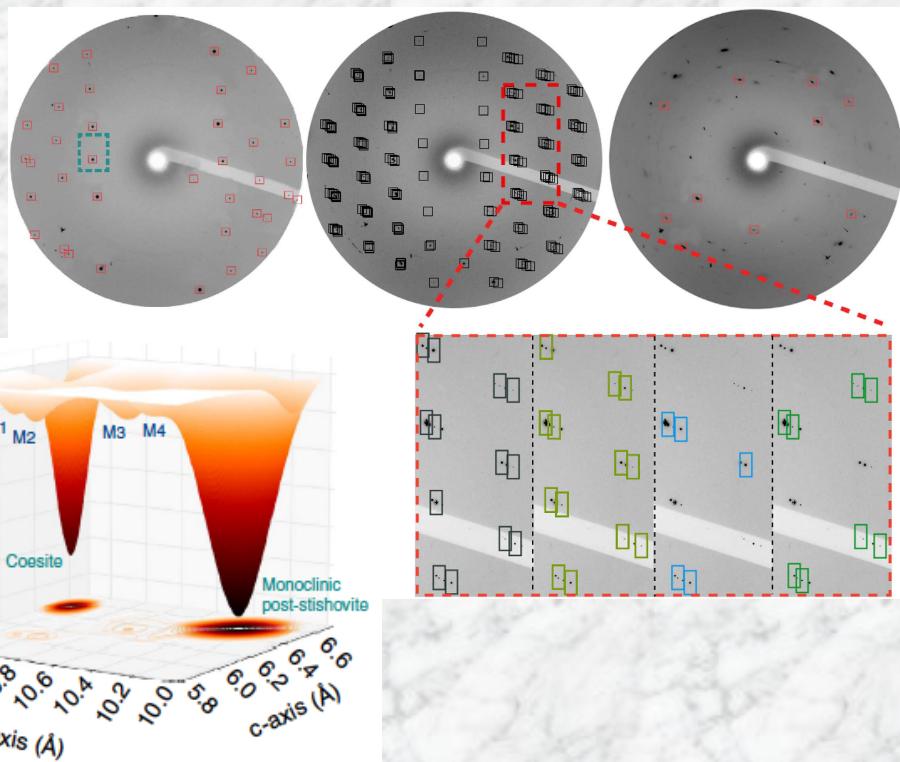
Xe(H₂)₇

Formed under HP



Xenon-hydrogen Solids under HP.

M. Somayazulu et al. Nat. Chem. 2009

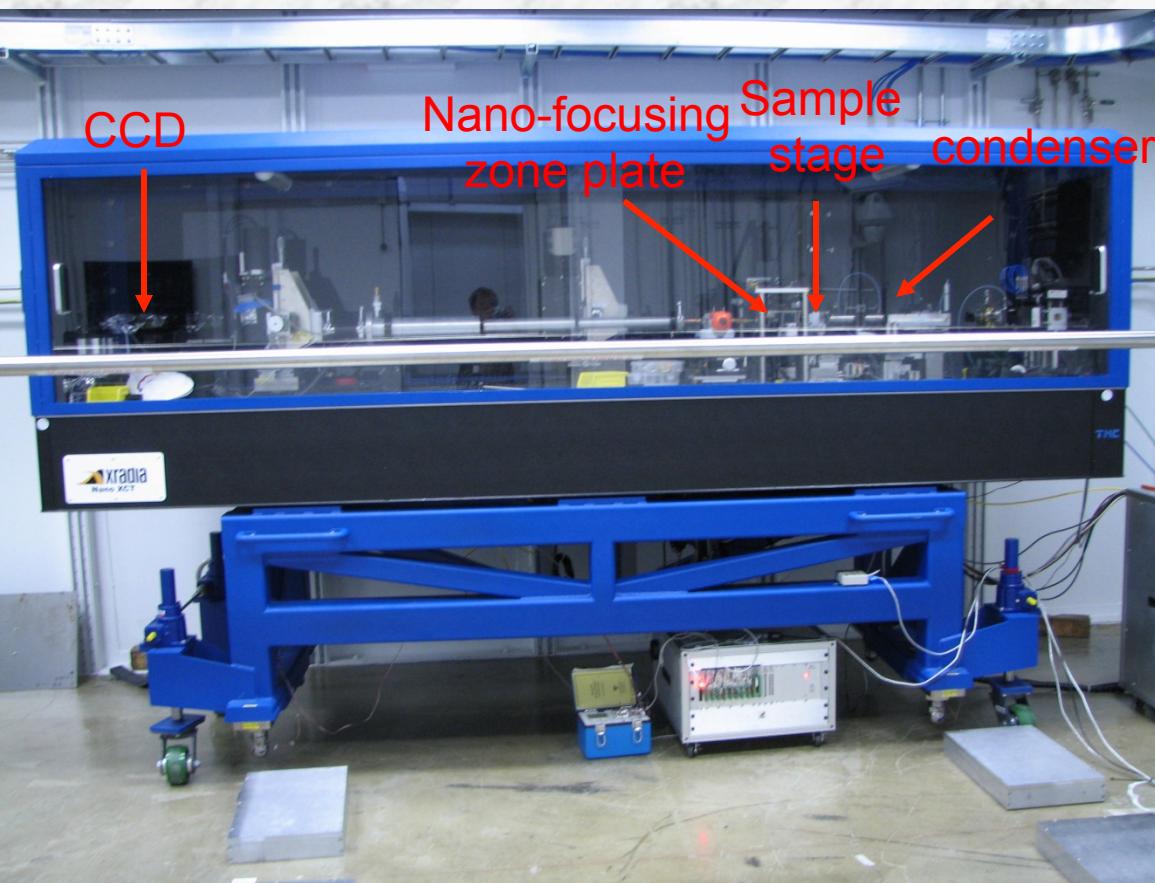


High pressure SiO₂ polymorphization revisit.

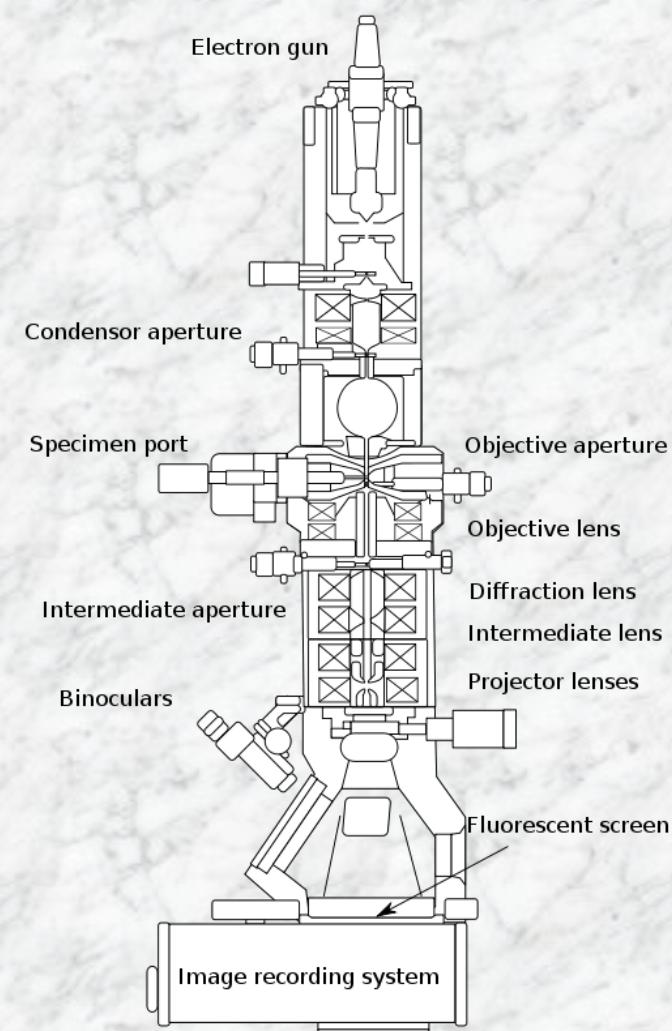
Coesite to Stishovite transition was considered via amorphization for 30 years, new single crystal study reveals Coesite → 4 Monoclinic intermediate phases (M1,M2,M3,M4) → Stishovite

Hu et al. Nat. Comm. 6, 6630 (2015)

Nanoscale imaging enables direct observation of studied object under high pressure
Transmission x-ray microscopy (TXM) setup at APS-32IDC and SSRL-6.2

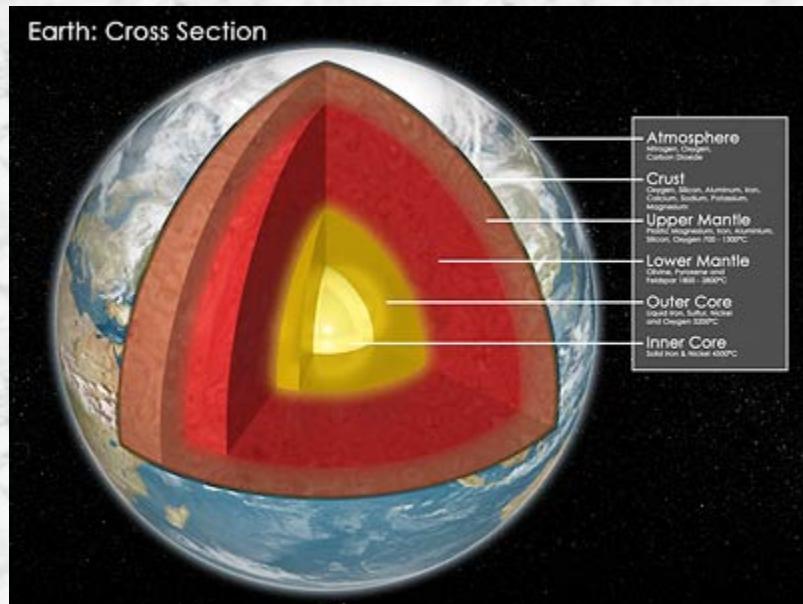


TXM vs. TEM



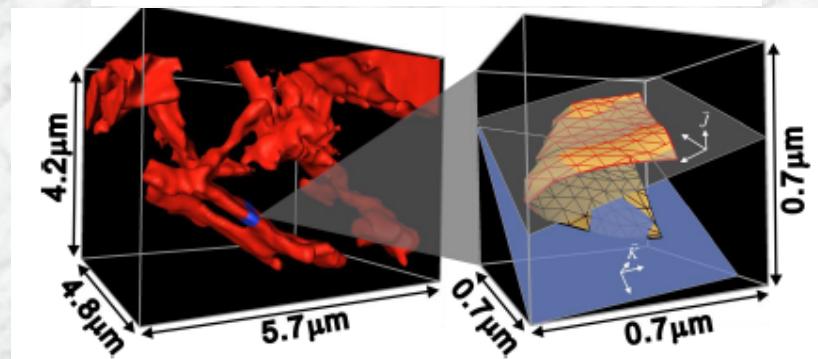
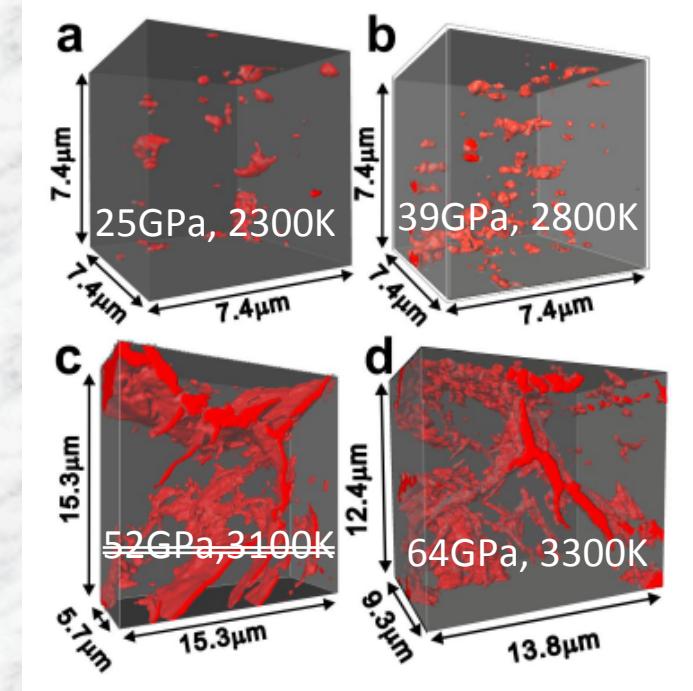
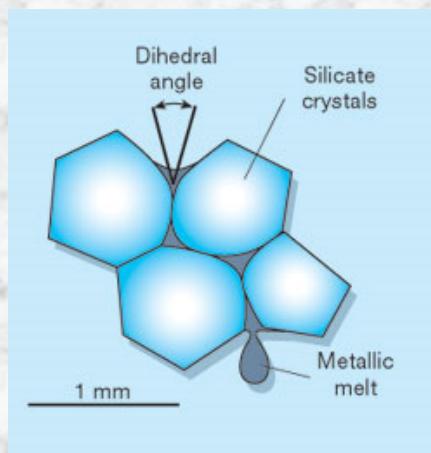
Capability: 30 nm spatial resolution in 3d;
in-situ shape, volume, even chemical
valence change under high pressure

Confirm of the formation mechanism of planet core with 3d nano-tomography



Bill Minarik "Planetary Science: The core of planet formation" Nature 422, 126 (2003)

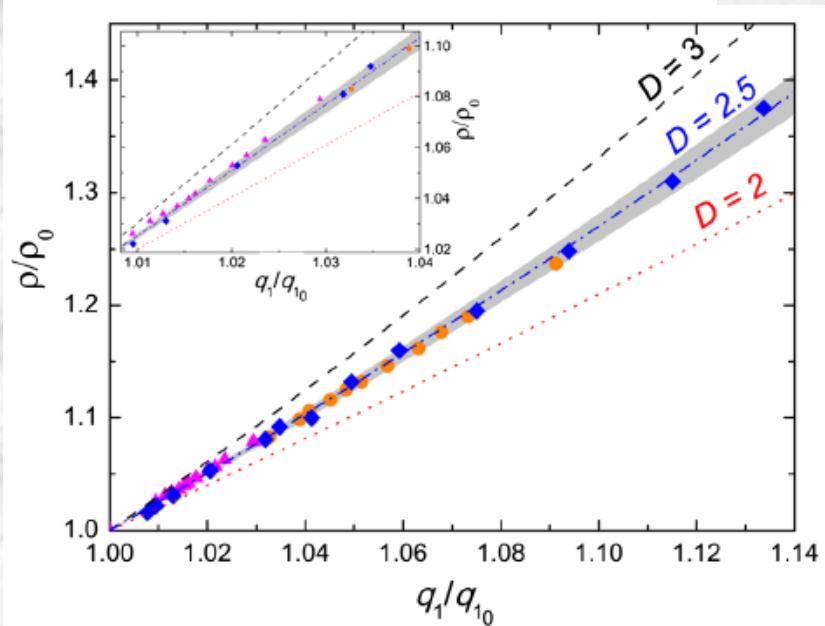
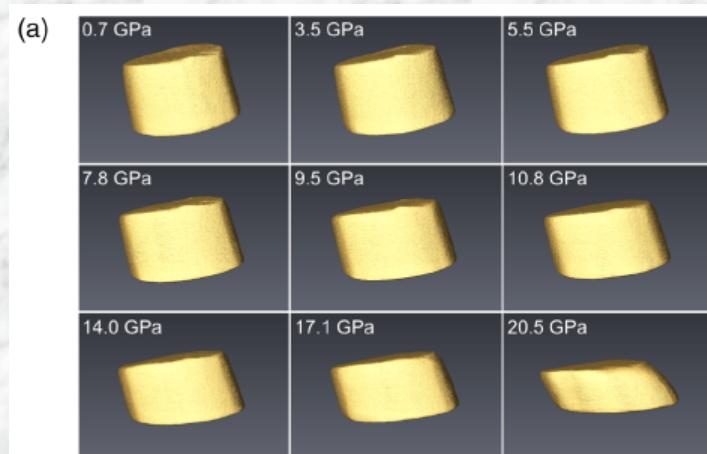
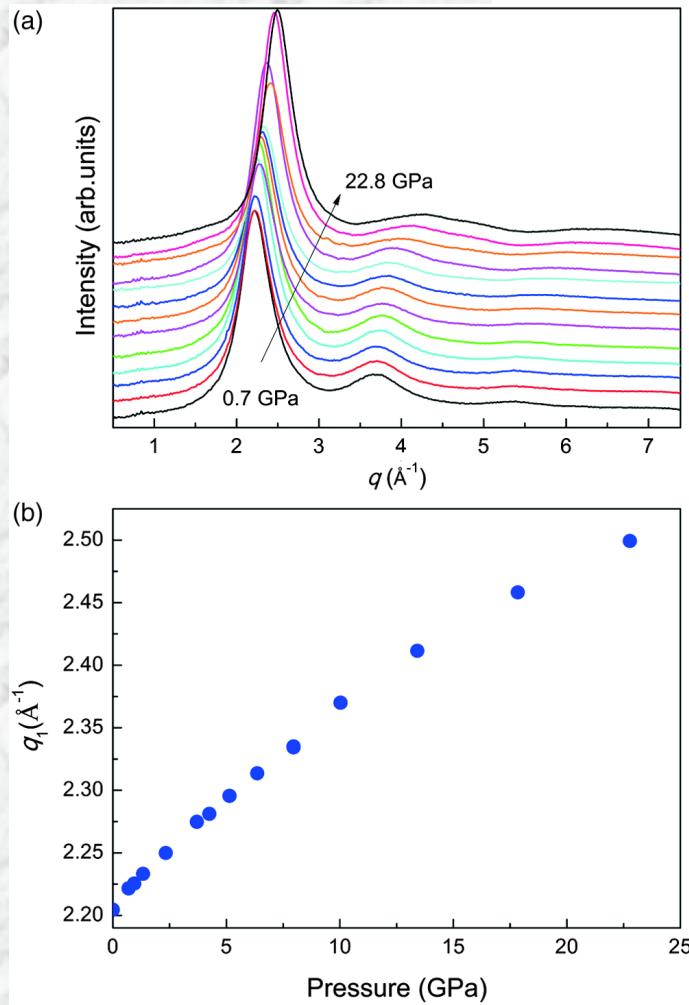
T Yoshino, et al
"Core formation in planetesimals Triggered by permeable flow", Nature 422, 154 (2003)



Shi et al. "Formation of an interconnected network of iron melt at Earth's low mantle conditions", Nat. Geoscience, 6:971 (2013)

Precise volume measurement of glass enable new power law check in metallic glasses

$$\rho/\rho_0 = (q_1/q_{10})^D \text{ (or } V/V_0 = (q_{10}/q_1)^D\text{)}$$

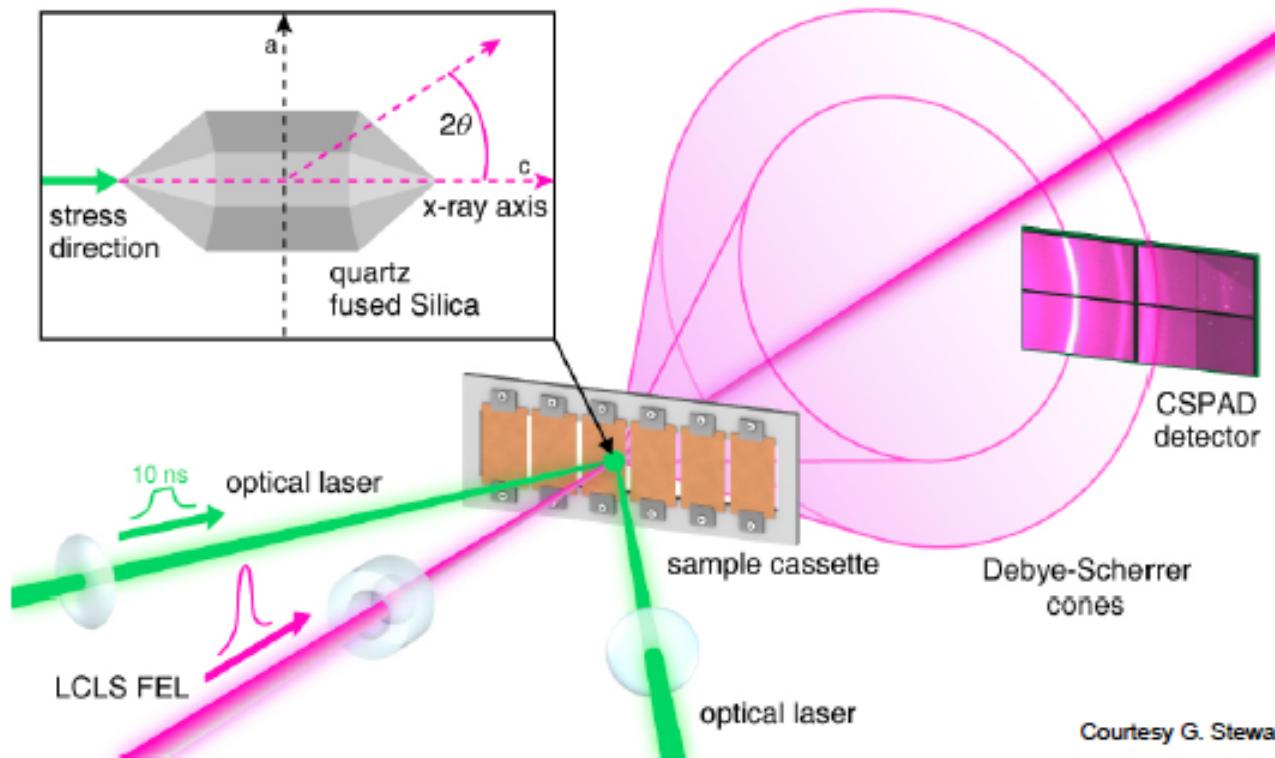


Zeng et al. "Universal Fractional Noncubic Power Law for Density of Metallic Glasses" Phys. Rev. Lett. 112, 185502 (2014); Chen et al. "Fractal atomic-level percolation in metallic glasses", Science, 349, 1306 (2015)

Beyond 3rd generation synchrotron --SLAC Linac Coherent Light Source



Pump-probe Diagnostics



Pump: optical drive laser with 10 ns square pulse, 200 – 300 μm spot, 5 – 32 J

Probe: LCLS xFEL with 100 fs pulse, 8 keV, 2 – 80 μm spot

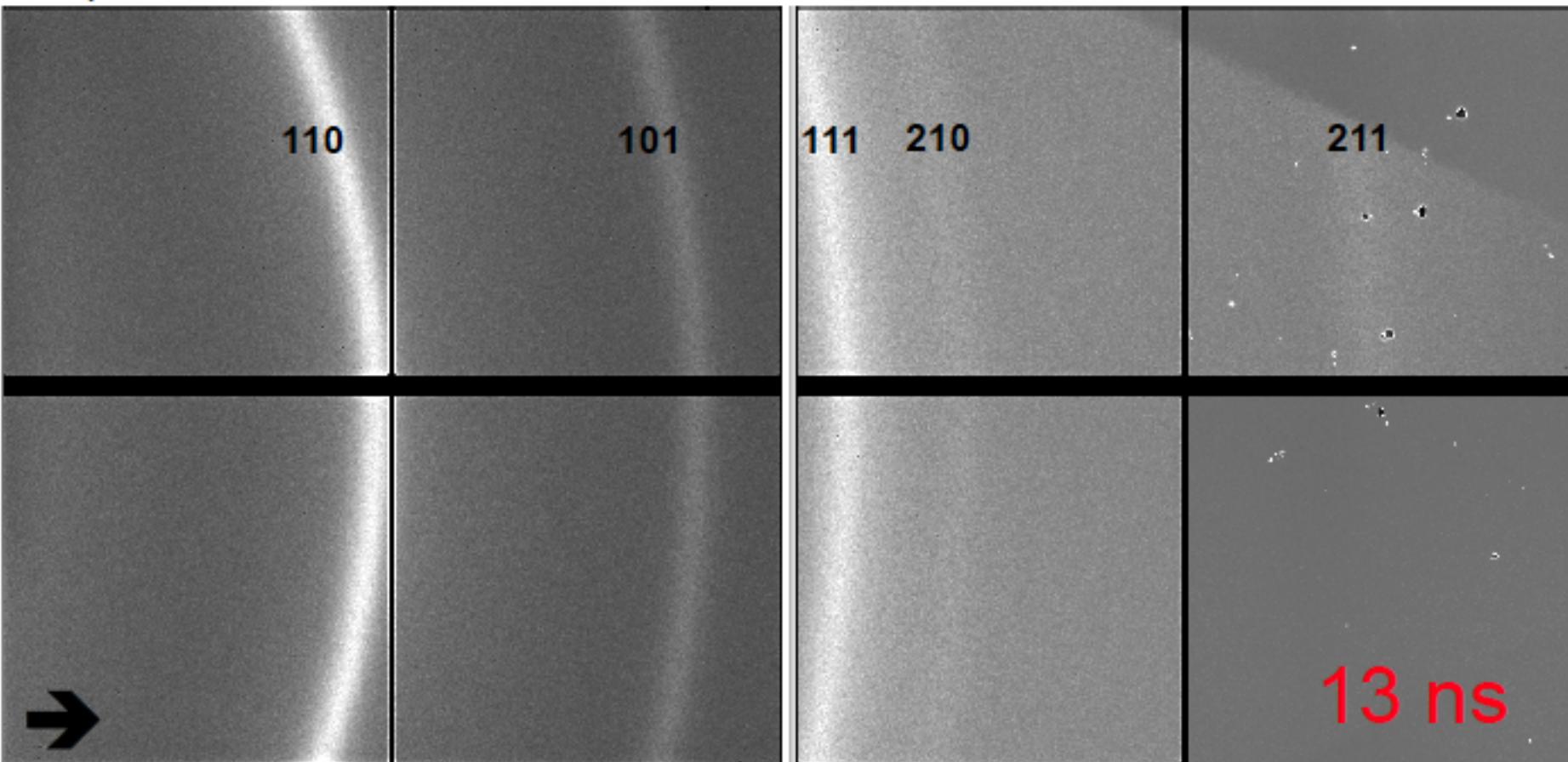
Time resolved structure transition induced by shock wave

Fused Silica to Stishovite

Run 451: 50 μm fused silica + 10 μm CH

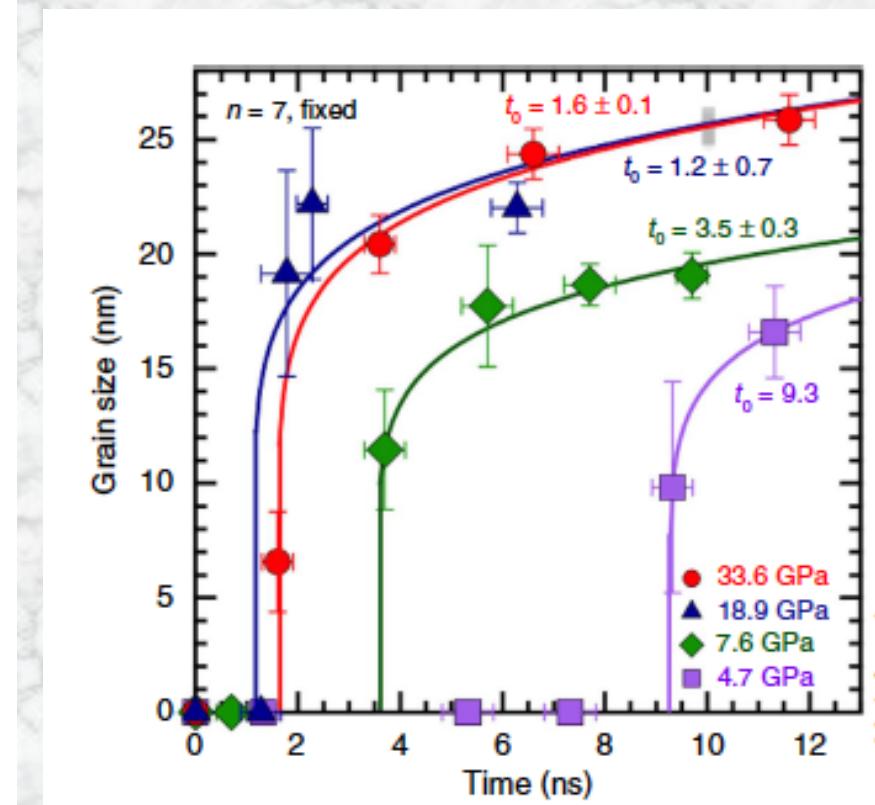
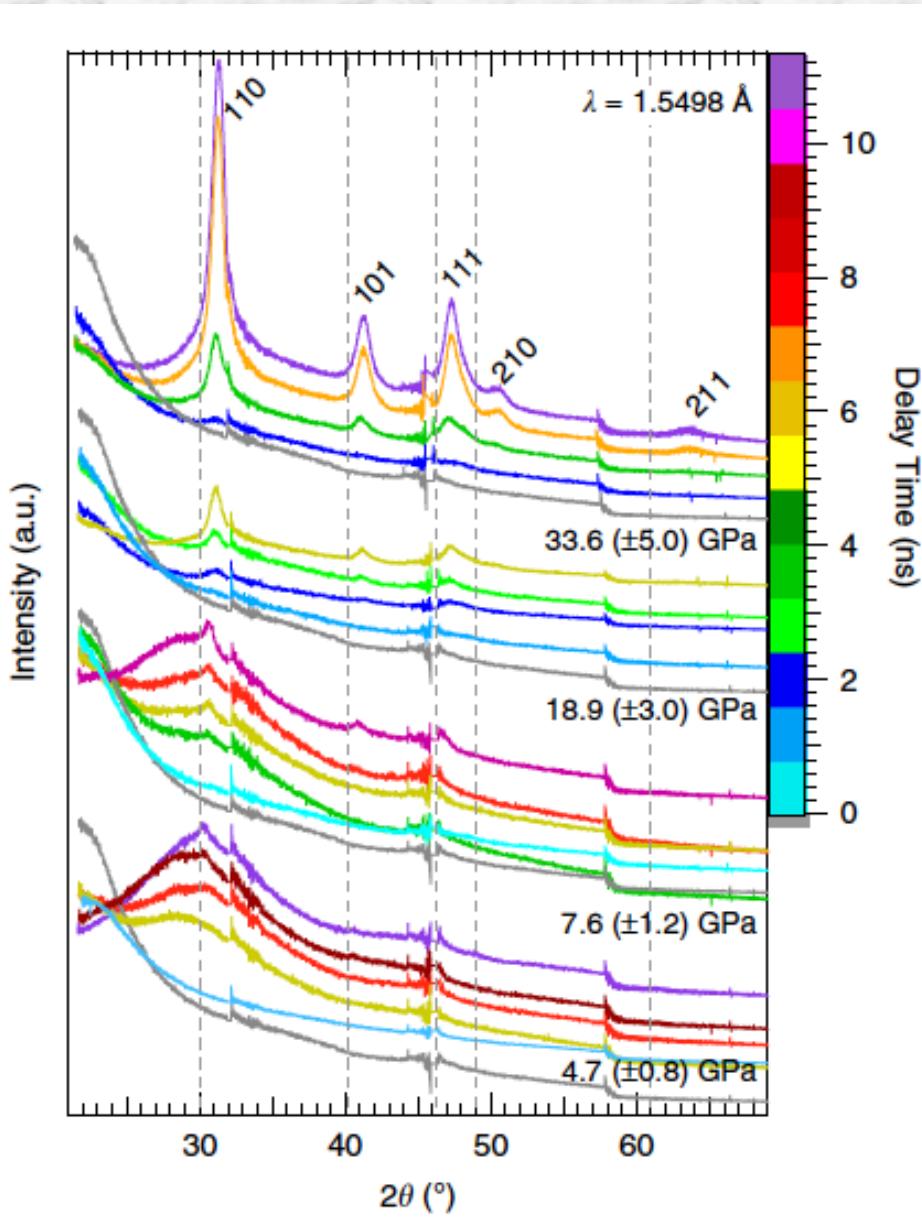
32 J, P \sim 78 GPa

FEL spot = 75 micron



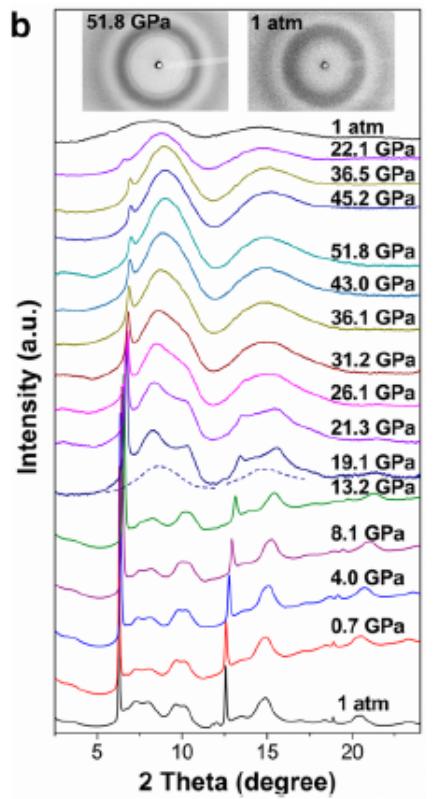
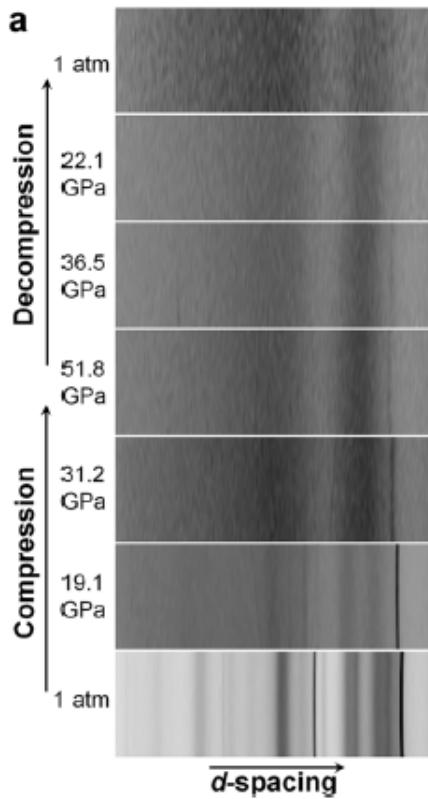
2 θ

Watching Laser-shocked stishovite grow in nanoseconds



Gleason et al. Nature Comm. 6:8189(2015)

High Energy Pair Distribution Function Provides atomic resolution



XRD
PDF
TEM

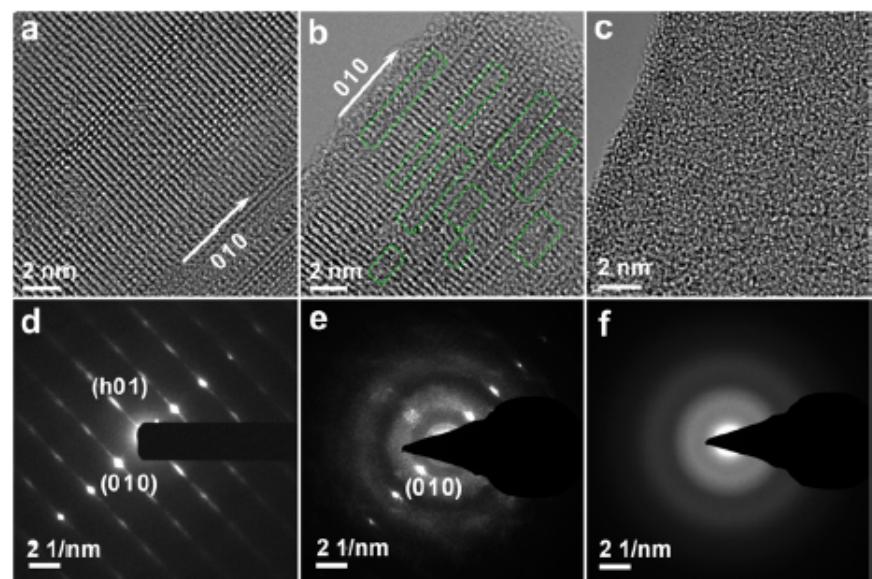
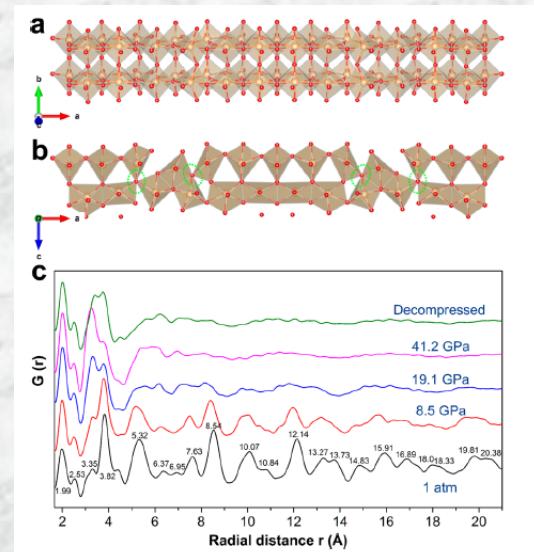


Figure 3. HRTEM images and SAED patterns of Ta_2O_5 nanowires from (a and d) pristine sample and recovered samples from (b and e) 19.2 GPa and (c and f) 51.8 GPa, respectively.

X. Lü et al.
“Pressure-Induced Amorphization in Single-Crystal Ta_2O_5 Nanowires: A Kinetic Mechanism and Improved Electrical Conductivity”
J. Amer. Chem. Soc. 135, 13947 (2013)

Outlook

Fast developments of novel synchrotron techniques provide us a great chance to study matter under various extreme environments.

Integration of multiple techniques allow us to get comprehensive understanding from all aspects.

A dedicated pioneer team on challenge research would create a fast pace on the frontier high pressure research.

The integration of HP and SR may potentially lead to the accomplishments of grant challenges in many disciplines, like:

Earth's inner core P-T conditions,

Terapascal pressure, warm-dense matter research,

Metallization of hydrogen and hydrogen storage capability,

Materials harder than diamond

Room temperature superconductor induced by pressure

Novel physical, chemical phenomena...